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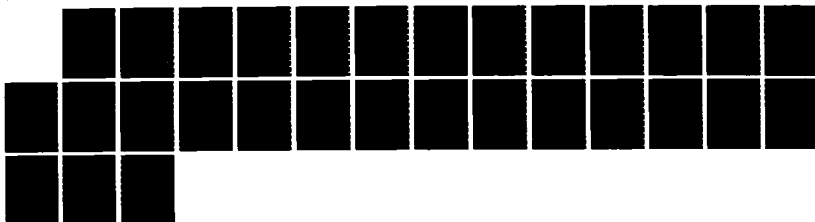
AIRBORNE OPTICAL SYSTEMS(U) KEO CONSULTANTS BROOKLINE  
NA R H EATHER 20 JUN 86 KEO-11 AFGL-TR-86-0133  
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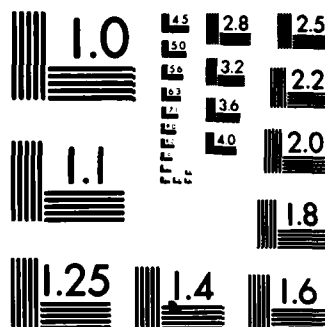
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AFGL-TR-86-0133

AIRBORNE OPTICAL SYSTEMS

Robert H. Eather

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27 Irving St.  
Brookline, Ma 02146

June 20 1986

Final Report  
June, 1982 - June, 1986

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
HANSCOM AFB, MASSACHUSETTS 01731

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"This technical report has been reviewed and is approved for publication"



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SECURITY CLASSIFICATION OF THIS PAGE

AD-A172173

## REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION <b>UNCLASSIFIED</b>			1b. RESTRICTIVE MARKINGS <b>NONE</b>	
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT  Approved for public release; distribution unlimited	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE				
4. PERFORMING ORGANIZATION REPORT NUMBER(S)  KEO-11			5. MONITORING ORGANIZATION REPORT NUMBER(S)  AFGL-TR-86-0133	
6a. NAME OF PERFORMING ORGANIZATION  Keo Consultants		6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION  Air Force Geophysics Laboratory	
6c. ADDRESS (City, State and ZIP Code)  27 Irving St. Brookline, Ma 02146			7b. ADDRESS (City, State and ZIP Code)  Hanscom AFB, Ma 01731	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION  Electronic Systems Div.		8b. OFFICE SYMBOL (If applicable) FQ7620	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER  F19628-82-C-0112	
8c. ADDRESS (City, State and ZIP Code)  Air Force Systems Command, USAF Hanscom AFB, Ma 01731			10. SOURCE OF FUNDING NOS.	
11. TITLE (Include Security Classification)  AIRBORNE OPTICAL SYSTEMS			PROGRAM ELEMENT NO.  62101F	
			PROJECT NO.  4643	
12. PERSONAL AUTHOR(S)  Robert H. Eather			TASK NO.  08	
			WORK UNIT NO.  AC	
13a. TYPE OF REPORT  Final		13b. TIME COVERED  FROM June, 82 to June, 86	14. DATE OF REPORT (Yr., Mo., Day)  June 20, 1986	
15. PAGE COUNT  28				
16. SUPPLEMENTARY NOTATION				
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB. GR.	photometers; spectrometers, low light level imaging; CCD camera system; aurora; airglow	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)				
<p>This work involved providing scientific, technical and engineering service to design, construct, test and calibrate a new airborne optical system for the Airborne Ionospheric Laboratory. The system measures low light-level airglow and auroral emission features, and consists of photometers, spectrometers, all sky intensified monochromatic CCD imaging, and data acquisition and instrument control electronics. The system includes special purpose software to facilitate all phases of instrument operation, data acquisition and recording, and real-time data display.</p> <p>This report provides an overview of the complete system, and refers the reader to detailed technical documentation provided separately in the form of user manuals.</p> <p><i>Raymond C. Chao, Chief Scientist</i></p>				
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT  UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input checked="" type="checkbox"/> DTIC USERS <input type="checkbox"/>			21. ABSTRACT SECURITY CLASSIFICATION  UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL  Robert Gowell			22b. TELEPHONE NUMBER (Include Area Code) 617 377 3035	
			22c. OFFICE SYMBOL  LIS	

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## 1. INTRODUCTION

This work involved providing scientific, technical and engineering support to design, construct, test and calibrate a new Airborne Optical System for the AFGL Airborne Ionospheric Observatory. The system is to measure airglow and auroral optical emission features, and consists of

- (i) A six-channel tilting filter photometer system, with a viewing telescope to allow full sky scanning.
- (ii) Two new scanning spectrometers (vertical pointing) to cover the wavelength range 375 - 825 nm.
- (iii) An all-sky imaging photometer system, with image intensification and telecentric optics for use with narrow band filters in a filter wheel configuration. CCD detector with high sensitivity and large dynamic range.
- (iv) A data acquisition system for the digital photometer and spectrometer data, with full programable control of the data collection process.
- (v) An image acquisition system for the LLL all-sky imaging photometer, with digital and analog recording and a range of image manipulation features.
- (vi) Fully documented software packages to perform tasks (vi) and (v) above.

All of the above hardware and software has been designed, tested, and delivered. This final report gives an overview of the system. Detailed technical documentation is found in the Users Manuals provided with the system, and described in Section 4, 6 and 7 of this report. This documentation includes photographs of the various mechanical and electronic subsystems, and appropriate calibration and test data. Two complete copies of all documentation have been provided to AFGL.

## 2. PHOTOMETERS

### A. OPTICS:

It was required to design a 6-channel photometric system that could be pointed to any coordinates in the upper hemisphere of the sky, and such that the scanning optics would fit into a 18" dia dome mounted on the top of the aircraft.

The following possible designs were considered

- a) Two mirror scanning system. This was rejected for the following reasons
  - (i) whole assembly must rotate for azimuth scanning
  - (ii) size constraints of dome limits mirror size, which in turn limits filter size (to 1 1/8" dia best design of this type), with consequent loss of light gathering ability.
  - (iii) dichroic separation limits spectral selection flexibility
- b) a Cassegrainian telescope system with image transfer down into the aircraft by mirrors and relay lenses. This was rejected for the following reasons
  - (i) mechanical difficulties, and optical losses in the optical relay system
  - (ii) subsequent spectral separation optically inefficient as not all collected light is used when 3 filters are placed within the telescope beam
  - (iii) dichroic separation limits spectral selection flexibility.
- c) The design finally chosen was a Newtonian telescope system with light transfer into the aircraft via a fiber optics assembly. (See Optics Documentation) This system offered the following advantages:



- (i) simplified and standard two-axis telescope scanning system
- (ii) light collecting efficiency of a system like this is limited by maximum filter diameter obtainable and maximum acceptable beam angle through the filter to maintain narrow filter passband. For the 3A filters specified, these numbers are  $\sim 2 \frac{1}{4}$ " and  $5^\circ$  respectively. As the required field of view is also  $5^\circ$ , this means that only  $2 \frac{1}{4}$ " dia of the telescope collecting area can be usefully used per filter. As the maximum telescope diameter that fits within the dome constraints is approximately  $5 \frac{1}{2}$ ", and

$$5.5^2 = 6 \times 2.25^2$$

it follows that the fiber optics splitting of the telescope image into 6 legs still allows complete use of the available throughput for  $2 \frac{1}{4}$ " dia 3A filters

- (iii) the fiber optics splitting allows complete flexibility for spectral selection

The optimum telescope design was selected by computer analysis that, within the mechanical constraints of dome size, maximized primary mirror size and minimized secondary obscuration, consistent with required maximum field of view of  $5^\circ$  and practical constraints on the fiber optics maximum diameter.

The final design chosen was as follows:

Primary mirror dia	5.5"
Primary mirror focal length	7.5"
Size primary image	0.66"
Secondary mirror (flat)	2.25" x 3.18"
Percentage secondary obscuration	20 %
Field lens	1" dia, 1" focal length
Image size at fiber optics input	0.75"
Size of fiber optics output	0.31"

The field lens and randomized fiber optics ensure the six photometer channels view the same area of sky. The maximum beam half-angle traced through the system is as follows:

Telescope field of view	2.5°
Fiber optics input	16.6°
Fiber optics output	16.6°
At filter	2.5°
At pm tube	16.6°

The optics schematic for beam collimation and reimaging in the tilting filter chambers is shown in The Optics Documentation.

The following 2 1/4" dia filters were provided with the system:

Center wavelength(A)	Halfwidth(A)	Transmission at Peak (%)
4284.7	5.8	25
4866.0	3.7	19
5205.5	2.7	28
5580.3	2.9	33
6304.2	3.3	47
7781.3	3.1	29

#### B. AZ/EL MOUNT

The Newtonian telescope and az/el scanning system is shown in The Optics Documentation. The az/el mount was supplied by Trax Instruments. Stepper motors drive the telescope via timing belt drives, such that each motor step corresponds to 0.05° change in azimuth or elevation. An analysis of mount/motor compatibility is provided with the Az/El Mount manual.

Elevation scan is  $\pm 85^\circ$ , and azimuth scan  $\pm 170^\circ$ . Electrical limit switches are provided at these limits, with mechanical limit stops just outside these limits. In addition, there is electrical indication of 0° on both axes.

High linearity potentiometers are mounted on each axis for analog readout of elevation and azimuth.

A custom designed electronics chassis is provided to control the az/el mount in the half-step mode. This unit features

- (i) Superior Electric stepper motor controllers with appropriate pulse ramping logic for start/stop
- (ii) manual (high and low speed) or remote control of both axes
- (iii) indicator read-outs of limit and zero positions
- (iv) digital readout of azimuth and elevation

#### C. FILTER CHAMBERS

There are 6 separate filter chambers. The optics schematic is shown in the Optics Documentation. Filter tilting is via a stepper motor and cam arrangement, such that tilting rates up to 5 Hz may be selected. Tilting range from 0-10° is accomplished by 50 motor steps, and the filter may be stopped if desired at any selected angle. An optical interrupter switch gives a 0° indication.

A temperature sensor and surface heating elements control filter temperature to within  $\pm 1/2^{\circ}\text{C}$ , and the filter temperature is independently adjustable for each unit. Adjustment and temperature readout is provided by a custom Temperature Controller Chassis.

The fiber optics input is attached by a simple push/detent hold arrangement. A mechanical shutter is provided for manual shuttering of each channel.

#### D. TEMPERATURE CONTROLLER

A custom designed temperature controller allows independent proportional control of filter chamber temperature. Temperature is set on 10 turn potentiometers and displayed on a digital readout. In addition,

photomultiplier tube temperatures for each photometer channel (and two spectrometer channels) are digitally displayed.

#### E. PHOTOMULTIPLIERS AND HOUSING

EMI photomultipliers were selected as the best available for low level pulse counting applications. To give maximum versatility, 4 bi-alkali (#9893B/350) tubes and two tri-alkali (#9863B/350) tubes were provided.

The tubes are mounted in thermoelectric coolers (Products for Research Model TE 182RF), capable of cooling to 40°C below ambient, with the addition of a temperature sensor for remote readout of tube temperature on the custom Temperature Controller.

An adjustable resistor is also provided in the HV line to allow trimming of pm HV for individual tubes.

#### F. Amplifier/Discriminators

The pulse output from the photomultiplier is fed to a high speed amplifier/discriminator (Pacific #AD6) which give out a TTL compatible pulse, 10 n sec wide. The pm tube/AD6 combination allow pulse rates in excess of 50 mHz.

#### G. POWER SUPPLIES

The following power supplies are used in the system

- |       |  |                   |
|-------|--|-------------------|
| (i)   | HV -2KV/10mA (for photomultipliers)                          |                   |
|       | Pacific Instruments 204-10                                   |                   |
| (ii)  | ±15V/1.8A (for Amplifier/Discriminators)                     | Lambda LYD-X-152  |
| (iii) | 12V/6A (for filter stepper motors)                           | Lambda LYS-Y-12   |
| (iv)  | 6V/60A (for PM tube coolers)                                 | Lambda LYS-K-6-0V |
| (V)   | 5V/5A (for limit switches, zero position sensors, and logic) | Lambda LUS-9-5    |

The last 4 supplies are mounted in a multi-supply chassis. All are capable of working from 115V, 50-400 Hz.

## H. JUNCTION BOX

A junction box is provided to route low and high voltage power, HV, stepper motor pulses, pm output pulses etc. between the 6 photometer heads and common system electronics. This box also contains digital logic circuitry for stepper motor pulse code generation and filter indicator electronics.

## I. PHOTON COUNTING INTERFACE

A custom design Photon Counting Interface was designed to take the pm tube pulses from the 6 photometer (and 2 spectrometer) channels, and format them under computer control for subsequent recording. In addition, the unit was designed to give analog outputs, independent of computer control.

- (a) Digital Data: The photon counting boards are capable of counting in excess of 50MHz, and accumulating counts up to  $2^{24}$ . The commands to each board from the computer are start count, halt count, reset counters and output enable; when counters are halted, the previous count is loaded to an output buffer.

The six photometer channels are wired in parallel for start, halt/load and reset commands, so that pulse integration times are identical and synchronous for all channels. Output enable commands are separate for all boards. (The two spectrometer boards are individually addressable for all commands.)

- (b) Analog Data: Separate analog channels are provided for all 6 photometer (and 2 spectrometer) channels. The pulse rate is fed to a F-V connector that generates a d.c. voltage proportional to pulse rate. To cover the dynamic range, a High/Low ( $\pm 100$ ) switch is included. The d.c. output is also fed to a logarithmic converter, so the final output chosen may either be linear or logarithmic. In addition, a LED bar graph display for each channel gives a visual indication of count rates.

### 3. SPECTROMETERS

Initial spectrometer consideration involved evaluation of the possibility of modifying the drive system on the old spectrometers to allow modern computer-controlled stepper motor scanning. Quotations obtained for new drive systems were extremely expensive (double the cost of complete new spectrometers) so it was decided to completely replace the old instruments.

An exhaustive search of available commercial instruments led to the selection of the Instruments SA HR-640 instrument, with modular controller.

#### A. OPTICS:

The HR-640 instrument uses Czerny-Turner optics and was purchased with the high aperture (F5.2) optics and 110x110mm 1800 g/mm holographic gratings. Variable slits were purchased for dual entrance and exit ports, with electrically activated entrance mirror assembly. Specifications include a dispersion of 18Å/mm, resolution of better than 0.15Å, and stray light rejection of better than  $10^{-5}$ .

The commercial instrument was modified as follows:

- (a) Slit height was increased and field lens added at the slits to maximize throughput
- (b) With the 1800 g/mm gratings, the mechanical wavelength readout (designed for a 1200 g/mm grating) was of no use. Consequently we changed the gearing ratios of internal coupling belt drives to give the correct wavelength readings for these gratings.

Input optics was designed to meet the following requirements

- (i) Field of view  $5^{\circ} \times 5^{\circ}$  square onto sky.
- (ii) Masking to restrict input light to 110x110 mm square beam at the grating.

- (iii) Field lens to allow maximum slit height for maximum throughput.
- (iv) Spectrometers must look through 6" x 6" (max) size windows in the top of the aircraft.

The input optics design is shown in The Optics Documentation. Provision was also made to mount a calibration source at the second input port.

Output optics was designed to meet the following requirements.

- (i) Field lens to allow maximum slit height
- (ii) Converging lens selected to fully image output beam onto the deeply recessed photocathode of the RCA GaAs photomultiplier tubes chosen, as mounted inside a thermoelectric cooler.

The output optics design is sketched in The Optics Documentation.

#### B. PHOTOMULTIPLIER AND HOUSING

To obtain wide spectral response up to 850 nm, a gallium arsenide photocathode was chosen, and the photomultiplier tube used is the RCA C31034. As the photocathode chip is recessed into the tube, the converging lens had to be mounted as an integral part of the frost free double window of the thermoelectric super-cooler (Products for Research Model TE 206 RF). This cooler is capable of cooling to 60°C below ambient. The frost free double window is provided with some heating to prevent any frost forming on the input optics. This cooler was also provided with a temperature sensor for remote readout of tube temperature on the custom Temperature Controller.

An adjustable resistor is also provided in the HV line to allow trimming of pm HV for individual tubes.

#### C. AMPLIFIER/DISCRIMINATORS

Same as for photometers, see A6 above.

#### D. POWER SUPPLIES:

The following power supplies are used in the system

- (i) HV -2kV, 2mA (for photomultipliers)  
Bertran PMT-20A/N
- (ii)  $\pm 15\text{V}/1.8\text{A}$  (for Amplifier/Discriminators)      Lambda    LYD-X-152
- (iii) 12V/20A (for PM Tube Coolers)      Lambda    LYS-W-12

The last two power supplies are mounted in the multi-supply chassis. All are capable of working from 115V, 50-400 Hz.

#### E. SPECTROMETER CONTROLLERS

Each spectrometer is controlled by a Modular Controller (Instruments SA #F304.35) which is programmed with a complete scanning package, including a RS232C or 8 bit-parallel link to the host LSI 11-23 computer. Programmable functions include From and To wavelengths, Scan and Slew speeds, reference position calibration, number of scans, delay between scans, chart recorder control, and safety shutter operation. A key pad module also allows complete off-line programming and operation independent of the host computer.

#### F. JUNCTION BOX

This is a passive box that simply divides/combines outputs and inputs from common control chassis to the two spectrometers. It contains no active electronics.

#### G. PHOTON COUNTING INTERFACE

The custom designed Photon Counting Interface (see A.9 above) also handles the two spectrometer channels. All of the features described under A.9 above apply, with the additional flexibility that each spectrometer channel is individually addressable for all commands. This allows spectrometer integration times to be independently set, depending on the parameters of each spectrometer scanning program.



#### 4. HARDWARE DOCUMENTATION FOR PHOTOMETERS AND SPECTROMETERS

The following manuals, calibration and test data have been provided for the individual system components

A. Optics Documentation - consists of details and drawings of the following:

Newtonian telescope design  
Fiber optics 6-leg assembly  
Filter chamber optics  
Az-el scanning mount  
Spectrometer optics  
Spectrometer input and output optics

B. Commercial Manuals:

(i) Lambda Custom Power Supply System - consists of instructions and manuals for

Standard Power Systems II

LRA-17		Rack Adapter
LYS-W-12	12V/20A	Power Supply
LYS-K-6-0V	6V/60A	Power Supply
LYD-Y-152	±15V/1.8A	Power Supply
LYS-Y-12	12V/6A	Power Supply
LYS-9-5	5V/5A	Power Supply

Keo wiring modifications

(ii) HV Power Supply - consists of instructions and manuals

for

Pacific Instruments Model 204-10 (-2kV, 10mA)

Bertran Model PMT-20A/N (-2kV, 2mA)

Keo wiring modifications

Note either power supply could run all 8 photomultipliers in the event that one supply failed.

(iii) Photomultipliers - consists of

EMI specifications for 9893/350 Q tube  
EMI specifications for 9863/350 Q tube  
Dynode chain/socket schematics 9863/9893  
6 x individual calibration curves for EMI tubes  
RCA specifications for C31034 tube  
Dynode chain socket schematics for C31034

(iv) Photomultiplier Coolers - consists of manuals for

Products for Research Model TE 182 RF  
Products for Research Model TE 206 RF

(v) Amplifier Discriminators - consists of

Pacific Instruments manual for AD6

(vi) Spectrometers - consists of manuals for

Instruments for Research SA HR-640 Spectrometer  
Instruments for Research SA Modular Micro-  
processor Scan Controller, with Keo modifications.

(vii) Computer - Consists of manuals for

DEC computer system and expansion boards  
DSD800 - D/30 30 mB Winchester + 1 mB Floppy  
Subsystem with Controller  
SA - BA11N - 1 4x8 Backplane and power supply  
KDF 11 - AA PDP11/23 Processor with MMU  
DLV11 - J Serial line interface  
DRV11 - J Parallel line interface  
LA100 - AA DEC Writer III  
VT 100 - AA DEC CRT  
C22/140 - 00 M Timer (Codar Technology)

(viii) Tape Recorder - consists of manuals for

Kennedy 9000 Digital Tape Transport

Western Peripherals TC151 Taper Formatter

(Hardware, Logic, Diagnostics Manuals)

C. Custom Electronics Manuals

(i) Temperature Controller - consists of

Manual for RFL TC10A-RTD Temperature Controller

(commercial item)

Manual for Analog Devices AD2037 6-channel

Scanning Thermometer

Manual for Analog Devices AD2038 6-channel

Scanning Thermometer

Manual for Analog Devices AD2040 Temperature

Indicator

Manual for Analog Devices AD590LF Temperature

Transducer

Keo designed circuitry and controls

(ii) Az/El Mount Control - consists of

Superior Electric Slo-Syn Stepper Motor Data

Superior Electric STM1800 Controller Data

Az/El Mount Wiring Schematic (Keo)

Platform Controller Schematic (Keo)

Platform Controller Format Conversion Logic (Keo)

Platform Controller Angle Readout Schematic (Keo)

Platform Controller Connection Schematic (Keo)

Analog Precision Potentiometer Shaft Readout

Calibration (Keo)

Transmissive Switch data sheet

Analysis of motor sizing compatability (Keo)

(iii) Filter Chamber - consists of

Japanese Products Motor Data

Honeywell Optical Switch Data

Wiring Diagram (Keo)

Filter Transmission Curves (Barr Assoc.)

(iv) Photon Counting Interface - consists of

PM Pulse Board Layout (Parsec)

PM Pulse Counter Board Schematic 1 (Parsec)

PM Pulse Counter Board Schematic 2 (Parsec)

PM Pulse Board Interface Logic (Parsec)

Back Plane Connections (Parsec)

DRV11 Interface Connections (Keo)

Frequency to Voltage Converter (Keo)

Divider Circuit (Keo)

Bar Graph Display/Voltage Regulates (Keo)

DRV11 Interface Descriptive Writeup (Parsec)

Display Calibration Procedure Writeup (Keo)

(v) Junction Boxes - consists of

Wiring schematics - input/output connections (Keo)

Filter Stepper Motor Interface schematics (Keo)

Filter Zero Indicator schematics (Keo)

(vi) Cabling - consists of

Complete connector and pin specification for the  
following cables

1. From Photometer Junction Box

<u>No.of Cables</u>	<u>To</u>	<u>Connectors</u>	<u>Description</u>
1	Temperature Controller	MS3116F14-19P/19S	Fiter temperature sensors
1	Temperature Controller	MS3116F14-19PW/19SW	PM Tube temperature sensors
1	Temperature Controller	MS3106A20-21S/21P	Filter heaters
1	Photon Counting Interface	MS3116F14-15P/15S	PM Pulse signals
1	Lambda P/S	MS3106A24-9S/9P	PM Tube Coolers 6VP/S
1	Lambda P/S	MS3106A16-9S/9P	Stepper Motors + 5V/12V P/S for Junction Box
1	Lambda P/S	MS3106A14S-7S/7P	+15V P/S for Discriminators
1	Lambda P/S	MS3106A14S-7SX/7PX	Cooler Fans
1	As/EI Mount Controller	MS3116F14-15SW/15PW	Stepper motor pulses + position indication
1	HV P/S	UG932U/UG932U	PM Tube HV
6	Photometer Heads	Amphenol 165-29/30	Stepper motor + indicator + heaters + temp. sensor
6	Amp/Disc.	MS3106A10SL-3S/Lemo	±15V
6	PM Tube Coolers	UG932U/UG932U	PM Tube HV
6	PM Tube Cooler	Coax/Coax	PM Tube Pulses
6	PM Tube Cooler	MS3106A14S-6P/6S	6V power + fan power + temp sensor.

## 2. From Spectrometer Junction Box

<u>No. of Cables</u>	<u>To</u>	<u>Connectors</u>	<u>Description</u>
1	Temperature Controller	MS3116F8-4P/4S	PM Tube temperature sensors
1	Photon Counting Interface	MS3116F10-6P/6S	PM Pulse Signals
1	Lambda P/S	MS3106A22-11S/11P	PM Tube Coolers 12V P/S
1	Lambda P/S	MS3106A145-7SW/7PW	± 15V P/S for Discriminators
1	Lambda P/S	MS3106A14S-7SY/7PY	Cooler fans
1	HV P/S	UG932U/UG932U	PM Tube HV
2	Amp/Disc	MS3106A10SL-3S/Lemo	± 15V
2	PM Tube Cooler	MS3106A16S-1S/1P	12V Power + Fan power + Temp. sensor
2	PM Tube cooler	Coax/Coax	PM Tube pulses
2	PM Tube cooler	UG932U/WG932U	PM Tube HV

## 3. From Az/El Controller

<u>No. of Cables</u>	<u>To</u>	<u>Connectors</u>	<u>Description</u>
1	Az/El mount	MS3126F14-19SX/PX	Azimuth control
1	Az/El mount	MS3126F14-19SY/PY	Elevation control
1	LSI11/23	40 pin ribbon	
1	LSI11/23	40 pin ribbon	

## 4. From Photon Counting Interface

<u>No. of Cables</u>	<u>To</u>	<u>Connectors</u>	<u>Description</u>
1	LSI11/23 DRV-11	40 pin ribbon	
1	LSI11/23	40 pin ribbon	

## 5. LLL IMAGING PHOTOMETER SYSTEM

### A. OPTICS:

The system is provided with an all-sky ( $170^\circ$  f of v) lens which forms a 75 mm image at F4.0 at the filter position. Four filters are selectable by a filter wheel. The image is then re-imaged to 24 mm diameter onto the faceplate of a 25mm 2nd Gen image intensifier. The intensified output image is reimaged to 13 mm dia. onto the CCD using fast, high resolution relay lenses (95 mm f1.4 + 50 mm f0.75).

Full lens specifications and image intensifier specifications are provided in the documentation.

### B. CCD:

The CCD used in the new Tektronex 512 x 512 front illuminated device. This CCD is superior to any previously available, in that pixel readout noise is 10 electrons and saturation signal is 700 K electrons. Full specifications are provided in the documentation. The square array is ideal for this circular image application.

### C. CAMERA HEAD:

The Photometrics CH183B Camera Head employs a 3-stage thermoelectric cooler to maintain an operating temperature of  $-40^\circ\text{C}$ . The detector is mounted in a hermetic chamber which is filled with an inert gas to prevent condensation. Special design was required to configure the very fast (f0.75) relay lens with its back focal length of 5.5 mm and required cover glass thickness of 2.3 mm; the cover glass and rear of lens actually projects into the CCD header cavity. (See documentation for details.)

The analog processor is mounted in The Camera Head and is a fixed gain correlated double sample circuit with 12 bit digitization at a readout speed of 100 khz.

### D. CAMERA CONTROLLER:

The Photometric CCl80A Camera Controller provides all the timing for the operation of the camera and to interface the camera with the host computer. Sixteen codes allow complete control of CCD operation and readout parameter specification, as

well as control of external shutter and calibrate lamp. (if installed)

E. DIGITAL IMAGE PROCESSING SYSTEM:

The computer is a single board CPU (Heurikon Corp.) in an expanded 14-slot Multibus enclosure, with a floppy disc drive and 55 mB Winchester disc. The computer has 1 mB of RAM memory (or board or CPU memory) and 4 mB of image/display memory. This allows simultaneous storage of a large number of digitized pictures (16 at full resolution, 32 with 2 + 2 binning), more than sufficient for this application.

Selected digital images may be recorded on the Kennedy digital tape transport at 1600 BPI. Analog images are selected as each new image is obtained by a video switcher for recording on a time-lapse VTR or an optical disc. Appropriate image annotation is applied via a header on the digital tape records, or by alphanumeric overlay on the analog recordings.

F. DISPLAY:

Up to four stored images may be displayed simultaneously on TV monitors via the 4 scan connectors included in the system. Three of these connectors are synchronized to allow RGB psudo color display.



## 6. HARDWARE DOCUMENTATION FOR LLL IMAGING PHOTOMETER

The following manuals, calibrations and test data have been provided with the system.

### A. Front End Optics Assembly

All Sky lens (Keo)  
Ilex shutter  
Rodenstock relay lenses  
Special camera head interface (Keo)  
Varo Image Intensifier  
Filter Wheel (Keo)

### B. CCD Array

Photometrics general descriptive literature  
Tektronix TK512M Data Sheets

### C. Camera

Photometrics Operators Manual  
(describes CH183B Camera Head and CC180A Controller)

### D. Digital Image Processing System

Users Manual Heurikon 68/M10, with Appendices to  
Users Manual  
Hbug Users Manual for HK68  
Heurikon MLZ-814 Users Manual  
Heurikon FDIO SBX Expansion Interface Users Manual  
Model M2896-63 Flexible Disc Drive Users Manual  
Maxtor XT-1000 Winchester Drive Users Manual  
Adaptec ACB - 4000 Disc Controller Users Manual  
Omnibyte OB68K230 Parallel Interface Board Users  
Manual with Keo special interfaces

Zendex ZBX - 288 Clock/Calendar Users Manual

Micro Term ERGO 301 Users Manual

IO Inc. SCSI902 Tape Drive Controller Users  
Manual

Kennedy 9000 Tape Drive Users Manual

Kennedy 9220 Embedded Formatter Users Manual

Photometrics DIPS Users Manual

#### E. Display

Panasonic WV 5352 Dual Monitor Manual

Sony PVM - 1271Q RGB Monitor Manual

Panasonic WJ - 521 Sequential Switcher Manual

## 7. SOFTWARE

### A. Photometers and Spectrometers

Software has been provided to control the following mechanical functions of photometers:

- (i) Filter tilting via stepper motors. Filters for 6 channels may be independently tilting or driven to a fixed angle
- (ii) Az/el mount via stepper motors. Telescope may be driven to any position, or programmed for repetitive scanning sequences. Pointing may be referenced to aircraft navigated information.

Software has been provided to control the following mechanical functions of the spectrometers. Each spectrometer is independently controllable.

- (i) Drive to a specified wavelength and dwell; repeat to other wavelengths
- (ii) Slow scan specified wavelength intervals with fast slews between these intervals.
- (iii) Repetitive combinations of the above.

Software has been provided to control data acquisition from the photometers and spectrometers, and record on digital tape. There are eight addressable pulse counter circuits (6 for photometers and 2 for spectrometers), with programmable integration times (independent for photometers and spectrometers). Data block headers contain all relevant housekeeping information for later analysis.

These custom software routines have all been written in FORTRAN with machine language subroutines where appropriate. Full descriptions and program listings are provided in the Software Documentation package.

## B. LLL Imaging Photometer

The standard software package provided with the Photometrics camera system controls all aspects of camera operation and image acquisition. Features include full array image, sub arrays, pixel binning for lower-resolution super-pixel images, programmable integration times, flat fielding corrections, background correction, etc. Image display capabilities include squeeze, zoom, pan, interactive cursor modes, line plot overlays, multi-image screen, alphanumeric housekeeping data overlay, etc. In addition, image statistics are available for real time display (min, max, root mean square pixel count).

Custom Keo software adds many features specifically developed for this application, including filter wheel control (with image readout during filter change cycle), programmable image intensifier high voltage, four addressable scan converters (three synchronized for RGB display), image selection for analog (VTR or optical disc) or digital (Kennedy Tape Transport) recording.

Full descriptions and program listings are provided in the Software Documentation package.

## 8. SOFTWARE DOCUMENTATION

### A. Photometers and Spectrometers

This is all special purpose software developed especially for this application. Software has been provided on floppy discs with full descriptive documentation and program listings. There is interactive operator control via screen prompts of all aspects of data acquisition.

### B. LLL Imaging Photometer

This system is provided with software to control all aspects of CCD camera operation and image acquisition. This is propriety Photometrics Ltd. software for which a license has been purchased. Documentation includes the following manuals:

Photometrics DIPS Users Manual

Io Fourth Manual

Io Forth Dictionary

Understanding Forth Overview

ERGO GR 301 ReGIS Graphics Reference

Micro Term Plot - 10 Graphics Option

In addition, special purpose software tailored to this specific application has been provided and is described in the manual Special Keo Software.

## 9. CONCLUSIONS

Tested hardware and software for all three new optical instruments has been designed, constructed and delivered to AFGL. It is AFGL's responsibility to arrange for installation of this new equipment on board the Airborne Ionospheric Observatory. All new instrumentation represents state-of-the-art upgrades of the old instruments, and will lead to greatly increased flexibility of operation and quality of data acquisition.

The overall optics instrumentation is a complex system, and with use it is expected that experience will dictate desirable hardware and software changes, modifications and improvements. It is anticipated that support for ongoing development will continue to be provided by Keo through a recently acquired follow-on contract.

END

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